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A TENTATIVE ESSAY IN THE ECONOMIC EFFECT OF SNOW REMOVAL OF THE--ETC(U)
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TENTATIVE ESSAY IN THE ECONOMIC EFFECT OF SNOW REMOVAL OF THE STREET NETWORK

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The author discusses his observations of a city with heavy snowfall in order to measure expenditures, snow removal operations, and capacity to insure traffic flow. According to the author no previous attempts have been made to gauge actual economic effect of snow removal.

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1. Introduction.

The modern city exists as a center of information exchange, administrative function, and commercial activity. However, it would not be an exaggeration to say that its functions, that is, its activities all stem from the maintenance of traffic and that the life of the city depends upon that traffic, and that the city is the product of its traffic. Because of this, when, even for only a short period of time, traffic is suddenly paralyzed due to some event such as a heavy snowfall, the lives of the city's people fall into chaos. For this reason, I went to a city where I could observe heavy snowfalls to measure expenditures, snow removal operations, and capacity to insure traffic [flow].

In general, beyond expending sizable sums, it is appropriate that we calculate their efficiency and, again, even more than determining these results, it is of prime importance that we may hereafter be able to make these expenditures more efficaciously. But, as concerns the street snow removal discussed here, there have been no previous attempts to gauge actual economic effect. Let us examine the following several reasons for this.

a). The heavy-snowfall belt is comparatively sparsely populated and additionally its traffic volume is low.

b). It goes without saying that there is a strong feeling of resignation concerning the accumulation of snow in winter.

c). There are many stoppages of winter-time industrial operations and, moreover, a large portion of types of industries such as agriculture cannot but be stopped.

d). It has not been customary to promote public works while measuring economic effect.

e). Especially in the case of highway snow removal, while snow removal is an annual occurrence, when spring comes the snow melts naturally; furthermore, it leaves no tangible traces.

f). An easily applied method for estimating the economic effect had not been developed.

However, in recent years, population has become concentrated even in the cities of the heavy-snowfall belt, and accompanying the evolution of "motorization", there has been a sudden increase in highway traffic volume. Also, the industrial framework has changed in order to sustain dense populations; the trend has switched from one shift [work shift] industries to two and three shift industries that have come to operate their production facilities continuously. Consequently, the importance of highway snow removal in winter has increased and gradually the amounts invested in it have become enormous. On the other hand, when the expenditures became great, naturally, their efficiency was questioned, and the idea that we had to promote these projects while gauging their economic effects became important. However, again, a method of estimating their economic effect had not been developed. Highway snow removal is particularly important to cities and their outlying districts; in addition, the method of expressing its results is complicated, and whatever one might say, since it is a short-lived phenomenon, simply adapting a method for estimating the economic effect on ordinary roads has been an insoluble problem.

This study evaluates economic effects one by one and attempts to advance calculations from the point of view of the coordinate estimation method to determine and follow the process of the development of economic effect. That is, the economic effect unfolds according to the flow of traffic traveling along that road; and it stimulates the area's economic standard, even affecting the environs backing on that road. In other words, in the relationship between the flow of traffic which travels along the road and the area's economic structure lies the development of economic effect[1].

In my opinion, the results of observing th macroscopic nature of the traffic flow in detail have confirmed the hypothesis that traffic volume is irregular. Furthermore, I combined this with the traffic volume-production income function model, coordinated it with the direct and indirect benefits of highway snow removal, and tried to estimate by unit of currency. Also snow removal expenditures have not been itemized, but calculated as lump sums, and I have tried to estimate the economic effect and make a comparison of it with the value of its benefits.

2. View on Estimating the Economic Effect of Street Snow Removal.

In general, to estimate the economic effect of a road, the relationship of the traffic flow system to the area economic system is determined. Street snow removal, too, may be viewed in the same way. That is to say, if an accumulation of snow on the streets causes a negative change in the traffic flow system, then this traffic flow system which has retrogressed will bring about a decline in the city's economic activity.

However, street snow removal suppresses this negative change imposed upon the traffic flow system and the result is a reduction of the decline in the city's economic activity. This is the economic effect of street snow removal. Consequently, in this study, I just took the negative change which an accumulation of snow on the streets imposes upon the traffic flow system as a decrease in the traffic volume, and, secondly, I have tried to estimate how the decline of traffic volume affects the city residents' income.

(1) Decline of Traffic Volume With Respect to Snow Accumulation.

Normally, the largest portion of traffic within a zone i-j passes via the shortest through-road k, but when this is interrupted by a snow accumulation or when it falls into a jam, traffic becomes active on detour route 1. However, because traffic resistance on detour route 1 is great compared to that of the shortest through-road k (e.g., as manifested in the time necessary to travel it, etc.), the traffic being unable to overcome this resistance may be aborted. Accordingly, k is interrupted, or the traffic volume of the interval i-j is decreased by a jam.

I carried out the following investigation of the Sapporo City traffic flow in order to measure this decrease of traffic volume. That is, from Friday, August 18, until Tuesday, August 22, 1967, three days excluding Saturday and Sunday, I carried out my investigation of traffic volume at 262 points of the whole city from seven in the morning until seven at night. Moreover, I selected days with road conditions the same as on these investigation days and I conducted running-speed investigations using test vehicles[2]. Next, from Monday, January 8, to Thursday, January 11, 1968, four days, I investigated traffic volume as I had previously from seven in the morning until seven at night at 112 of the investigation points of the previous year's summer, taking the Olympic Way as well as the important snow removal arteries, etc., into consideration and conducted a running-speed investigation again in February of the same year. I extracted the summer and winter traffic volumes and the results of the running-speed investigations from this data; matched them; and computed the traffic work volume $\Sigma\, T_k \cdot t_k$ defined as the cumulative product of the traffic volumes T_k and the respective travel times t_k as outlined below (Figure 1).

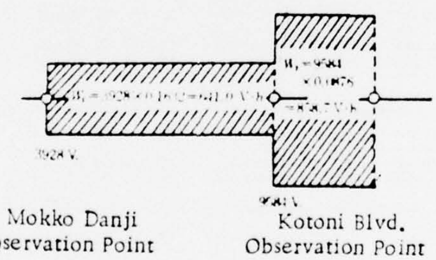


Figure 1. Traffic Work Volume Computation Method.

a). I drew a traffic flow zone diagram according to the point traffic volume.

b). I computed the average travel time split into distance intervals according to average travel speed.

c). I computed the traffic work volume of these intervals (vehicles × time) by multiplying the traffic volume (in this case taking the number of vehicles transiting the points in either direction during a twelve hour period) by the average travel time.

d). I computed the total traffic work volume for Sapporo City by totaling the traffic work volume of the respective intervals for the entire city.

CHART 1. A COMPARISON OF THE SUMMER TRAFFIC WORK VOLUME

Name of observation point	Length of route[1]	Summer avg. section speed[2]	Winter avg. section speed[3]	Summer travel time[4]	Winter travel time[5]	Summer traffic volume[6]	Winter traffic volume[7]	Summer traffic work volume[8]	Winter traffic work volume[9]
				$\times 10^{-3}$	$\times 10^{-3}$				
Entrance of Mokko Danji	6 250	38.3	33.1	163.2	188.8	3 928	3 018	641.0	569.8
Kotoni Blvd. Intersection	2 750	30.7	24.9	89.6	110.4	9 584	7 170	858.7	791.6
Kotoni Track Intersection	1 950	29.7	20.7	65.7	94.2	21 113	18 500	1 387.1	1 742.7
North 1 West 25	500	16.4	20.8	30.5	24.0	15 177	13 261	462.9	318.3
South 1 West 25	3 600	33.1	24.2	108.8	148.8	4 544	4 474	494.4	665.7
North 5 West 20	2 450	37.5	20.0	65.3	122.5	15 408	12 920	1 006.1	1 582.7
North 5 West 20	1 750	15.0	19.3	116.7	90.7	15 879	11 516	1 853.1	1 044.5
South 9 West 15	1 150	27.5	23.3	41.8	49.4	7 580	10 376	316.8	512.6
South 9 West 15	800	37.7	32.6	21.2	24.5	7 419	6 601	157.3	161.7
North 1 West 11	1 700	25.8	17.0	65.9	100.0	21 112	17 380	1 391.3	1 738.0
South 2 West 11	1 350	36.0	30.8	37.5	43.8	25 625	27 718	960.9	1 214.0
South 14 West 11	1 950	33.4	25.4	58.4	76.8	19 901	14 679	1 162.2	1 127.3
South 14 West 11	1 900	23.9	25.0	79.5	76.0	3 991	3 403	317.3	258.6
South 22 West 10	3 100	37.0	33.4	83.8	92.8	8 946	8 396	749.7	779.1
South 22 West 11	550	27.5	21.2	20.0	25.9	13 968	15 930	279.4	412.6
North 18 West 5	2 300	30.0	23.7	76.7	97.0	15 354	12 481	1 177.7	1 210.7
Minami O Dori West 5	2 050	15.8	14.0	129.7	146.4	11 545	9 885	1 497.4	1 447.2
South 1 West 6	700	14.2	12.7	49.3	55.1	3 413	3 340	168.3	184.0
South 4 West 5	750	32.5	16.5	23.1	45.5	2 110	9 941	48.7	452.3
South 9 West 6	1 150	37.6	21.7	30.6	53.0	23 371	20 394	715.2	1 080.9
South 9 West 7	1 200	24.7	22.5	48.6	53.3	16 053	12 980	780.2	691.8
North 5 West 4	150	21.9	10.4	6.8	14.4	13 578	12 346	92.3	177.8
North 5 West 3	400	24.6	13.4	16.3	29.9	14 249	18 651	232.3	557.7
North 3 West 2	1 650	15.0	14.4	110.0	114.6	16 587	12 701	1 824.6	1 455.5
North 3 West 2	2 300	11.3	7.8	203.5	294.9	10 814	10 362	2 200.6	3 055.8

CHART 1 (CONTINUED)

Name of observation point	Length of route[1]	Summer avg. section speed[2]	Winter avg. section speed[3]	Summer travel time[4]	Winter travel time[5]	Summer traffic volume[6]	Winter traffic volume[7]	Summer traffic work volume[8]	Winter traffic work volume[9]
North 1 West 3	2 050	12.4	14.4	165.3	142.4	15 273	12 170	2 524.6	1 733.0
North 1 West 4	500	13.7	13.9	36.5	36.0	15 908	13 870	580.6	497.3
North 1 West 3	2 250	30.8	14.3	73.1	157.3	22 471	20 021	1 642.6	3 149.3
North 1 West 4	350	10.0	11.0	35.0	31.8	16 821	14 941	588.7	475.1
North 1 West 4	750	26.2	17.3	28.6	43.4	22 229	22 109	635.7	959.5
South 1 West 4	2 050	17.7	10.9	115.8	188.1	9 618	7 997	1 113.8	1 504.2
South 1 West 3	1 200	8.3	9.4	144.6	127.7	9 245	8 537	1 336.8	1 090.2
South 1 West 4	1 150	16.3	15.1	70.6	76.2	13 587	17 131	959.2	1 305.4
South 1 West 4	800	32.2	18.5	24.8	43.2	20 501	13 219	508.4	571.1
Ishikari Mutsubashi	2 950	23.9	22.0	123.4	134.1	31 985	21 990	3 946.9	2 948.9
East 7 Chome Railroad Crossing	900	21.4	7.8	42.1	115.4	4 346	2 497	183.0	288.2
Higashi Bashi	650	17.2	24.3	37.8	26.7	35 641	20 968	1 347.2	559.8
Ichi 75 Bashi	500	21.3	20.5	23.5	24.4	19 747	16 867	464.1	411.6
Toyohira Bashi	3 200	31.9	21.1	100.3	151.7	33 510	30 065	3 361.1	4 560.9
Nandai Bashi	950	24.3	26.2	39.1	36.3	17 989	15 243	703.4	553.3
South 9 West 3	950	25.0	27.2	38.0	34.9	17 808	15 152	676.7	528.8
Korohei Bashi	450	26.2	24.8	17.2	18.1	14 751	12 969	253.7	234.7
Minami Nijunichito Bashi	650	27.3	32.0	23.8	20.3	10 970	8 895	2 610.9	180.6
Hokkaido Gakuen Mae	350	25.8	20.9	13.6	16.7	13 249	10 847	180.2	181.1
Nakano Shima Crossroads	1 150	37.3	31.5	30.8	36.5	7 950	7 518	244.9	274.4
Nakano Shima Crossroads	750	30.8	30.3	24.4	24.8	10 306	8 669	251.5	215.0
Minami Nijunichijo Intersection	3 800	29.5	29.4	128.8	129.3	13 492	9 942	1 737.8	1 285.5
Hirakishi Shogaku Yoko	1 800	38.0	26.2	47.4	68.7	8 884	5 718	421.1	392.8
Shira Ishi and Nakanoshima Intersection	1 800	34.1	36.3	52.8	49.6	23 359	16 018	1 233.4	794.5
Kamishiraishi Shozen Intersection	1 700	25.4	24.2	66.9	70.2	6 690	5 118	447.6	359.3

CHART 1 (CONTINUED)

Name of observation point	Length of route[1]	Summer avg. section speed[2]	Winter avg. section speed[3]	Summer travel time[4]	Winter travel time[5]	Summer traffic volume[6]	Winter traffic volume[7]	Summer traffic work volume[8]	Winter traffic work volume[9]
Tsuki Sappu Higashi 7 Chome	2 950	37.5	36.4	78.7	81.0	3 066	2 702	241.3	218.9
South 19 West 15	1 100	35.1	32.5	31.3	33.8	1 180	2 512	36.9	84.9
South 16 West 7	750	23.3	22.3	32.2	33.6	9 992	7 383	321.7	248.1
						751 817 100%	649 491 83.6%	49 329.3 100%	48 841.3 99%

[1]Length of route measured from the Sapporo City Planning Map 1/25,000 (unit: meters).
[2]Actual observation by the Sapporo City Planning Section (unit: kilometers (hours)).
[3] " (")
[4]Calculated by dividing length of route by the summer average section speed (unit: hours).
[5]Calculated by dividing length of route by the winter average section speed (unit: hours).
[6]Actual observation by the Sapporo City Planning Section (Chart of the Results of the SHOWA 42 (1967) Traffic Volume Investigation Observations - August, 1967) (unit: V).
[7]Actual observation by the Sapporo City Planning Section (Chart of Collected Calculations of the SHOWA 43 (1968) Winter Traffic Volume Investigation - January, 1968) (unit: V).
[8]The summer traffic work volume was calculated by multiplying the summer traffic volume by the summer travel time (unit: V·h).
[9]The winter traffic work volume was calculated by multiplying the winter traffic volume by the winter travel time (unit: V·h).

The results are as in Chart 1.

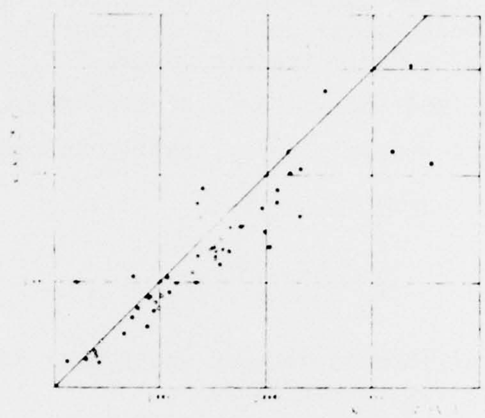


Figure 2. Comparison of Summer Traffic Volume with Winter Traffic Volume.

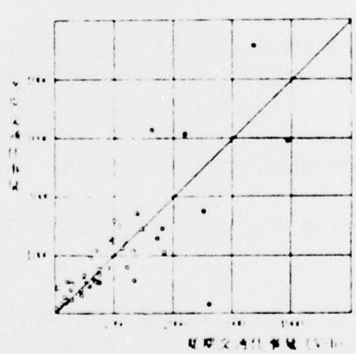


Figure 3. Comparison of Summer Traffic Work Volume and Winter Traffic Work Volume.

Figure 2 compares the summer traffic volume and the winter traffic volume at the various points, and as could be predicted, the summer traffic volume was greater than the winter traffic volume on most of the routes; however, the winter traffic volume was much greater on one portion of the routes. This may be because of the diversion from routes from which snow was not removed to routes from which snow was removed. As for the comparison of the totals of traffic volume points like this, if we take the summertime as 100%, the winter was 86.3%, and a difference of about 13.7% can be seen. On the other hand, if we look at the traffic work volume, as can be seen in Figure 3, the decline is similar, with the summer volume at 100%, the winter volume comes to 99% and the difference does not exceed a scant 1%. Of course, we cannot reach conclusions from this one fact, but if we can assume that in this one city the summer's daily traffic work volume will be constant in the winter; when we investigate the summer's daily traffic volume $\Sigma\, T_{0k}$ and average required travel time $\overline{t}_0$, and the winter's average required travel time $\overline{t}$, then we can calculate the winter's daily traffic volume $\Sigma\, T_k$.

$$W = \sum_k T_{0k} \cdot t_{0k} = \sum_k T_k \cdot t_k \tag{1}$$

$$\sum_k T_k = (t_0/t) \sum_k T_{0k} \tag{2}$$

Consequently, the difference between the summer daily traffic volume and the winter daily traffic volume ΔT is

$$\Delta T = \sum_k T_{0k} - \sum_k T_k = \sum_k T_{0k}(1 - t_0/t) \tag{3}$$

If we try to eliminate this difference by street snow removal, this is the road snow removal effect which is manifested as the difference of traffic volume.

(2) Traffic Volume-Production Income Function Model.

Following the road economic effect estimation method according to the Tinbergen model for the effect of snow removal which is manifested as the difference in traffic volume, I tried to construct a traffic volume-production income function model in order to express the difference in the city's residents' production of income.

a). The relationship of traffic volume to the production investment factor.

If we let the constant l be the load capacity of a vehicle and X be the production investment factor, there may be considered to be a proportional relationship between the vehicular traffic volume T and the factor X.

$$T = m'(X/l) + n' \tag{4}$$

$$X = l(T - n')/m' = mT + n \tag{5}$$

provided that $(l/m') = m$ is transposed to $(-ln'/m') = n$.

That is to say, if there is an increase in the production investment factor, the traffic volume will increase proportionately. Conversely, we can also say that an increase in the traffic volume means an increase in the production investment factor.

On the other hand, in our country of today the circulation of the production investment factor cannot neglect vehicular traffic. For example, even though a large portion of travel is by train, boat, plane, etc., on either end, generally, an automobile is involved. Because of this, if T = 0, then we may say that X = 0. Accordingly, when we make n = 0 in equation (5), we derive

$$X = mT \tag{6}$$

b). The relationship of the production investment factor to production income.

The relationship of the production investment factor to production income may be expressed by the so-called production function.

The production function generally satisfies the two following criteria[4].

(1). When the production investment factor X increases, production income Y increases (corrected as to the limits of productivity).

$$\frac{\partial Y}{\partial X} > 0 \tag{7}$$

(2). However, the rate of increase diminishes (the law of diminishing return of production investment factor)

$$0 > \frac{\partial^2 Y}{\partial X^2} \tag{8}$$

In the function model which satisfies these conditions,

$$Y = \alpha X^{\beta} \quad \alpha > 0,\ 1 > \beta > 0 \tag{9}$$

we can consider the exponential function above. That is to say,

(1). the corrected limit of productivity

$$\frac{\partial Y}{\partial X} = \alpha \cdot \beta X^{\beta - 1} > 0 \tag{10}$$

(2). the law of diminishing return is

$$\frac{\partial^2 Y}{\partial X^2} = \alpha \cdot \beta (\beta - 1) X^{\beta - 2} < 0 \tag{11}$$

If we adopt an exponential function-like equation (9) as the production function in this, we derive from this and equation (6) the following relationship of traffic volume to production income

$$Y = \alpha X^{\beta} = \alpha m^{\beta} \cdot T^{\beta} = aT^{b} \tag{12}$$

That is to say, the relationship between the traffic volume of that district T and of the production income Y may be expressed in the form of an exponential function-like equation (12).

I have provisionally named

$$Y = aT^{b},\ a > 0,\ 1 > b > 0 \tag{13}$$

the traffic volume-production income function model ([in English] traffic volume-product model).

(3) Method of Estimating the Economic Effect of Street Snow Removal.

The traffic volume-production income function is the prominent group above which should serve as a starting point.

Now, if the travel time t_0 plus t is increased by snow accumulation, we can calculate the decrease in traffic volume ΔT according to equation (3) by putting aside the assumption of a fixed traffic work volume.

Again, accompanying this decrease in trying to point out the traffic volume-production income function model, it seems that production income will decrease from Y_0 to Y. If we are able to suppress the increase in travel time by highway snow removal, the traffic volume will not decrease, and consequently, the decrease of production income will disappear. That is to say, production income ΔY, which prevented this decrease, is the economic benefit of road snow removal, and we can estimate the economic effect by comparing this to the expenses necessary for snow removal operations. That is to say, if we make B the economic benefit which is produced by this and if we make C the expenses which are necessary for snow removal operations,

$$B = \Delta Y \tag{14}$$

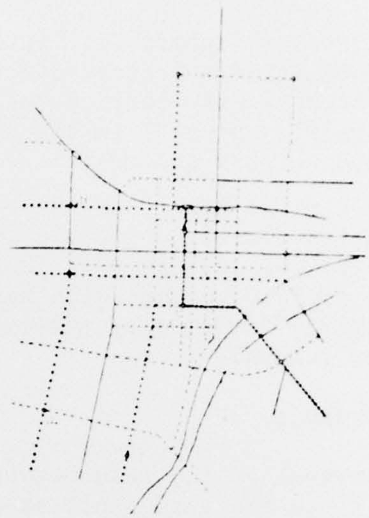
and the expense x benefit ratio a may be expressed as

$$a = B/C = \Delta Y/C \tag{15}$$

3. Estimation of the Economic Effect of Road Snow Removal in the Central Area of Sapporo City.

Every year Sapporo City expends great sums of over 400,000,000 yen carrying out snow removal operations when winter comes, striving to guarantee road traffic. As for this, much of the lives of the city's residents depends on the road traffic and this is because interruption of road traffic is directly related to interference with the lives of the residents of the city.

Snow removal eliminates this interruption of road traffic and is extremely important for the maintenance of the lives of the city's residents in an emergency. I have tried to determine this importance quantitatively, and to estimate it taking the central area of Sapporo City for my example, especially for the estimation of economic effect by the method which I outlined in the previous paragraphs.



a). Subject Area of Estimation.

The subject area of estimation is the central area of Sapporo City as shown in Figure 4. All the means of transportation of Sapporo City are concentrated in this central area and also a large portion of personal trips made for commuting to work or commuting to school pass through this area or have their starting or finishing point there. Accordingly, the paralysis of this area's traffic brings great harm to all areas of Sapporo City and to the lives of the people of the whole city.

b). The Minimum Base Road Network and Emergency Road Network.

Because national highways, main roads, city streetcar tracks and two or three other roads are the minimal roads essential to prevent isolation of areas, these are taken as the minimal base road network and must not be disabled. Generally, snow removal of national highways is carried out by the Hokkaido Development Bureau; main roads, Hokkaido; and streetcar tracks are cleared by the Sapporo City Traffic Bureau. When all of these roads are disabled, for example, even for a single day, there is a risk of fatalities among the aged or children. In addition to this there is the emergency living road network; in order to be able to utilize both the aforementioned minimal base road networks and the emergency living road networks, first of all the emergency living roads must be maintained. The snow removal funds which are expended by the Sapporo City Construction Bureau are the funds for the purpose of snow removal from this emergency living road network.

(1). Influence Exerted on Traffic Volume by Road Snow Removal.

I divided the central area of Sapporo City into zones according to the zone divisions of the 1968 Vehicle Traffic Starting and Finishing Point Investigation[5] which Sapporo City carried out in 1968; I sought the difference ΔT between traffic volume T in the case of snow removal on just the minimal base road network and traffic volume T_0 in the case of snow removal on both the minimal base road network and the emergency living road network through the following calculation process concerning the traffic volume and the various zone pairs. That is, this difference of traffic volume ΔT is the traffic volume which has been maintained by removing snow from the emergency living road network and may be considered as the effect of street snow removal.

Calculation Process.

1). The movement on the road network of traffic volume (emergency traffic volume) T_0 in the case where snow is removed from both the base road network and the living road network and traffic work volume W is calculated.

2). As for the living road network, let us hypothesize that it becomes congested by not being cleared of snow, and let us calculate the traffic work volume W' which has the small traffic volume T' from the emergency traffic volume T_0 in respect to the base road network which is opened up.

3). While compensating for T', I duplicated the calculation of 2) to find T' when W = W', and made this traffic volume T in the case where the base road network is cleared of snow.

4). I looked for the difference in traffic volume ΔT by subtracting traffic volume T in the case where only the base road network is cleared of snow from the emergency traffic volume T_0.

When I applied this to every zone pair which is related to the central area, the result was Chart 2. That is, the total difference in traffic volume was 17,692 vehicles.

(2). The Sapporo City Traffic Volume-Production Income Function Model.

We can express the benefit achieved by road snow removal as units of traffic volume, that is, vehicles by number of trips. As for that, how much does that traffic volume contribute to the formation of the city's production income? If we wish to be able to know this, we can express it as the economic benefit from road snow removal taken from the change of the amount of production income. We may use the traffic volume--production income function model for this.

CHART 2. EFFECT OF SNOW REMOVAL EXPRESSED AS DIFFERENCE IN TRAFFIC VOLUME

Zone pair	Traffic volume to (vehicles/day) when base and emergency net-works are cleared	Traffic work volume W (vehicles·time)	Traffic volume T (vehicles/day) when only base network is cleared	Difference in traffic volume (vehicles/day) $\Delta T = T_0 - T$
201-202	50 772	3 232	47 040	3 732
210-201	5 264	371	5 121	
220-202	14 010	1 409	12 498	1 512
211-201	9 778	869	9 589	189
211-202	33 310	2 578	26 068	7 242
212-202	6 679	893	6 637	42
213-201	15 859	1 341	15 680	179
213-202	36 138	2 243	35 771	367
213-210	2 103	193	2 082	21
214-201	12 396	1 077	12 115	281
214-202	8 095	962	7 899	196
215-201	11 130	808	10 804	326
215-202	8 232	516	7 585	647
216-210	12 013	1 326	9 615	2 398
217-201	13 488	891	13 364	124
217-202	16 657	1 416	16 555	102
217-213	4 505	581	4 346	159
217-214	2 466	217	2 434	32
	262 895	20 923	245 203	17 692

To construct the traffic volume-production income function model under actual conditions, I had to prepare simultaneous traffic volume investigation results and production income figures. However, there were the traffic volume investigations for 1962[6], 1965[7] and 1968[8] and city citizen income statistics from 1960 through 1968 for the City of Sapporo to be used as data for this; and among them, then, simultaneous data for each of the three points of 1962, 1965 and 1968. From these, I constructed the traffic volume-production income function model. Then for the city residents' essential daily income amount, I divided the city residents' annual income by 365 and then converted it into 1968 money according to the Sapporo City wholesale price index (Chart 3).

CHART 3. SAPPORO CITY RESIDENTS' DAILY INCOME AMOUNT AND TRAFFIC VOLUME

	Annual city citizens income[1] (1 000 yen)	City Citizens' daily income[2] (1 000 yen)	Price index[3] (1968 = 100)	Citizens' essential daily income[4] (1 000 yen)	Traffic volume[5] (vehicles)
1962	165 126 983	452 403	86.98	520 100	206 849
1965	257 866 288	706 483	93.40	756 352	395 807
1968	406 540 514	1 113 810	100.00	1 113 810	775 565

[1]The annual city residents' income from the results of a Sapporo City statistical investigation: report on an estimate of the income of the residents of Sapporo City.
[2]City residents' daily income = annual income/365.
[3]The price index is according to the Hokkaido Commerce and Trade Annual Statistical Report corrected so that the Sapporo City Wholesale Price Index of 1968 = 100.00.
[4]Essential daily residents' income = daily residents' income divided by the Price Index.
[5]The Sapporo City area (including Teine Machi) total automobile traffic volume (vehicles/day).

If we apply an exponential function like equation (13) using this data we obtain

$$Y = 451.259\, T^{0.576} \tag{16}$$

$$\frac{dY}{dT} = 259.925\, T^{-0.424} \tag{17}$$

(Figure 5).

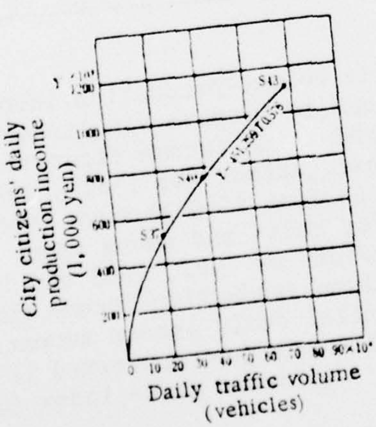


Figure 5. Traffic Volume-Production Income Function Model for Sapporo City.

With only a scant three years' data to substantiate this traffic volume-production income function model, I do not know whether or not it will be criticized as not being reliable. However, this model theoretically

CHART 3. SAPPORO CITY RESIDENTS' DAILY INCOME AMOUNT AND TRAFFIC VOLUME

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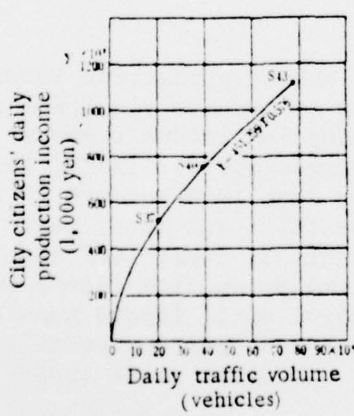

Figure 5. Traffic Volume-Production Income Function Model for Sapporo City.

With only a scant three years' data to substantiate this traffic volume-production income function model, I do not know whether or not it will be criticized as not being reliable. However, this model theoretically supports, as I have shown above, that the minimum square method does not apply alone. Furthermore, I think that this method of use can serve the purpose of this paper fully because it utilizes the relative values of the points for the year 1968 while interpolating.

(3) Expense • Benefit Ratio and Excess Benefit.

a). Value of benefits derived from road snow removal.

If we remove snow as completely as possible, vehicular traffic will approach the traffic volume of usual times and we will be able to ameliorate the harm caused by failure to remove snow so that the city residents' lives, too, will return to normal. The amount of this amelioration as I mentioned earlier may be considered as the value of the benefits of snow removal.

In (1) I calculated the influence of road snow removal in the central section of Sapporo City as 17,692 vehicles/day and asked what impart this had on the income of the residents of the city. In assessing thus, it was appropriate to use the traffic volume-production income function model which I constructed in (2).

From the equation (dY/Dt) = 259.925 $T^{-0.424}$ I obtained

$$(dY/dT)_{T=775,565}=0.827 \quad \text{(1,000 yen/vehicles)} \tag{18}$$

$$(dY/dT)_{T=757,873}=0.835 \quad \text{(1,000 yen/vehicles)} \tag{19}$$

That is, in the case of the daily traffic volume of 775,565 vehicles (1968), for one vehicle of traffic volume, 827 yen of production income was consumed and in the case of the 757,873 vehicles which when subtracted from this to yield ΔT = 17,692 vehicles, it consumed 835 yen. Because the 1968 city residents' essential daily income is Y = 1,113,810 thousand yen and the daily traffic volume is T = 775,565 vehicles, (Y/T) = 1.4361 thousand yen and flexibility η is

$$\eta=\left(\frac{dY}{dT}\right)\Big/\left(\frac{Y}{T}\right)=\frac{0.827}{1.4361}=0.576 \tag{20}$$

and the traffic volume-production income function model equation (16) index of T is equal to 0.576.

Well, if we do not remove the snow from the normal living road network, the traffic volume decreases to 757,873, but accompanying this how much lower will the production income be? This can be calculated simply from the following equation if we use the flexibility η.

From equation (20)

$$Y=\frac{(dY/dT)\cdot T}{\eta}=\frac{(dY/dT)\cdot T}{b} \tag{21}$$

T = 757,833 vehicles is

$$Y_T = \frac{0.835 \quad 757{,}833}{0.576} = 1{,}098{,}653 \text{ thousand yen.} \qquad (22)$$

The decline in the city residents' production income is

$$\Delta Y = Y_T - Y_T = 15{,}157 \text{ thousand yen.} \qquad (23)$$

However, this decline can be prevented by snow removal and the amount, that is, the value of benefit can be made B = ΔY.

b). Expense · benefit ratio.

According to the actual investigation of the Sapporo City Road Maintenance Department, road snow removal expenses of the type indicated in Figure 2 increased the personnel expenses of city workers and totaled 240,000 thousand yen for 1968. On the other hand, the snow removal period is December, January and February (three months) and because it is 90 days, the snow removal expenditure for one day C is

$$C = 240{,}000/90 = 2{,}667 \text{ thousand yen} \qquad (24)$$

and so we can calculate

$$\text{Expense} \cdot \text{benefit ratio} \quad \alpha = B/C = \frac{15{,}157}{2{,}667} = 5.7 \qquad (25)$$

The problem in this is the method of determining minimum base road network necessary for maintaining a minimum of the city residents' lives. This is because even the value of the benefit changes considerably in respect to the quantity of this. In this study I have referred to the opinions of the Sapporo City Road Maintenance Department and the City Planning Department and taken them as in Figure 4. Even if there were a change in the base network, the calculation procedure would be completely like that above.

4. Conclusion.

Returning to the basic point of the method for estimating road economic effects in this paper, first of all I studied the details of the phenomenological system called vehicular traffic flow and the phenomenological system called urban economic construction. The result was that I tried to calculate the economic benefits in currency units by an organic combination of both the previously established "Hypothesis of Fixed Traffic Work Volume" and the later traffic volume-production income function model which I constructed. I obtained the output from the normal expense-benefit ratio, plugged it into my value system and proposed a method for obtaining the economic effect of roads. Finally, I applied this method to the case of road snow removal in the central area of Sapporo City in 1968 and estimated the expense-benefit ratio as 5.7.

This method is culled from the customary methods of the total estimation method and its attained limit of economic effect is not local nor can its time of influence be applied in cases that are momentary. If the attained limit of its economic effect were local and if it were momentary, I think it would be sufficient to estimate the direct effect taking this as a base, calculating the surplus of traffic work volume (traffic volume × × average travel time) that may be produced if we do not build new roads, improve existing roads or repair roads. Hereafter many problems remain for the major points of this method which I have presented, the "Hypothesis of Fixed Traffic Work Volume", and the "Traffic Volume-Production Income Function Model". That is, this hypothesis and this model are lacking in corroborative evidence because there was only a small amount of data used in their construction.

In carrying out this study, I received the guidance of Professor Ogawa Kirojo of Hokkaido University from start to finish. Also, I received offers of valuable data from the Sapporo City Planning Section. I express my deep written gratitude to all of them.

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